Electricity Price Forecasting for the Electric Reliability Council of Texas Using Econometrics Models

Arturo Baca1* and Sara Emadou2

1Department of Mathematics and Statistics, Texas Tech University, Lubbock, USA.  
2Department of Electrical Engineering, Texas Tech University, Lubbock, USA.

Authors’ contributions
This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

Original Research Article

ABSTRACT

Short-term electricity price forecasting has been a prominent factor in many aspects of electrical power companies. Revolutionary changes in modern electrical grids so-called Smart Grids have introduced smart meters as essential parts of the Smart Grids, which increase the importance of Electricity price and load in the energy management system. Short-term electricity price forecasting has been a prominent factor in many aspects of electrical power companies over the last 15 years. Several modeling approaches, such as Fundamental models, Reduced-form models, Statistical Models, and Computational intelligence models, have been used by the researchers in the field. Among the Statistical models, the time series models have shown great performance. In this paper, we propose a new price forecasting method based on SARIMA-GARCH models with the Skew-Normal Distribution as electricity spot prices exhibit large deviations. The model is constructed to simulate and compose the estimated components of the time series model to predict the future electricity price for the Electric Reliability Council of Texas. Finally, the obtained results from the proposed model are compared with the Normal Distribution Assumption. The effectiveness of the presented method is verified by using real electricity price data from the Electric Reliability Council of Texas. This finding confirms that the forecast accuracy can be significantly improved by the proposed method.

Keywords: Electricity price; forecasting; econometrics time series; SARIMA.

1. INTRODUCTION

Forecasting of the electrical parameters in the power system, such as the behavior of components (Electrical machines, Electric Vehicles, capacitors and so on) and other elements like price and load has been a significant challenge. Precise electricity price
forecasting is an important aspect that guarantees financial and reliable power grids. Moreover, having accurate forecasting of electricity prices can help consumers and producers to take the most advantage of the precise prediction to maximize their benefits and optimize the utilities. Therefore, this seems essential to have an accurate forecasting model at short term electricity price. In recent years, several different methods for forecasting electricity prices have been presented by the researchers in the short term. The electricity price can be classified as a model with sophisticated features. This complexity cannot be met with a single model [1-5]. Consequently, the hybrid techniques have been proposed to address the price forecasting. In [6,7] a combination of neural network and wavelet transform was used to predict the price. A hybrid method of neuro-fuzzy, Monte Carlo simulation, and wavelet transform was proposed in [8]. A combination of regression and neural networks is a work that could get a lot of attention [9].

By considering the points as mentioned above, a SARIMA-GARCH model as a standard tool for modeling the conditional mean and volatility of time series with the Skew-Normal Distribution is used as electricity day-ahead prices which can exhibit large deviations in this paper. A model is constructed to simulate and compose the estimated components of the time series to forecast future electricity one day ahead prices. Finally, the obtained results from the proposed model are compared with the Normal Distribution Assumption. The effectiveness of the presented method is verified by using real electricity price data from the Electric Reliability Council of Texas (ERCOT). The Electric Reliability Council of Texas (ERCOT) manages the flow of electric power on the Texas Interconnection that supplies power to more than 25 million Texas customers – representing 90 percent of the state’s electric load.

2. METHODS

In this section, we shortly explain the methodology that we are applying in this research. We use real electricity price data from the ERCOT collected from the official website from 1:00 am 01/02/2011 to 11:00 pm 12/21/2018. Fig. 1 shows the electricity price process.

To have accurate forecasting of electricity prices, we need to work with a stationary process. Therefore, we carry out the traditional unit-root non-stationary tests to examine whether the electricity price process is non-stationary. The p-value (~ 0.86) of the Augmented Dickey-Fuller test provides strong evidence of the unit-root non-stationary process. As the price process shows non-stationary behavior, we need to transform the price process to a stationary process using the form of a function. The most important of the functional forms that we use in time-series regressions is the natural logarithm. We obtain the log-returns of the price process by the logarithmic return as follows:

\[ r(t) = \ln \frac{S(t)}{S(t-1)} \]  

where \( S(t) \) is price at day \( t \). Fig. 2 shows time series return process.

The p-value of the Augmented Dickey-Fuller test for the return process is about zero indicating strong evidence of rejecting the unit-root non-stationary process. To check the presence of conditional heteroscedasticity, we perform the McLeod-Li test. As the test p-value is about one, the test does not provide evidence for rejecting the existence of conditional heteroscedasticity in the return process. Thus, to have a correct prediction, we should eliminate serial dependence and volatility clustering from the return process. To do so, we apply standard econometrics time series models to derive sample innovations. Instead of studying the return process, we consider their sample innovations derived from the time series models. [10] and [11] used sample innovations instead of return process to study the stock market’s dependence behavior. Consequently, we have independent and identically distributed (iid) standardized residuals in the model and expect to have an accurate prediction.

Econometrics is an active field that widely used for modeling and predicting time series data. It has been widely used in engineering, economics, business, finance, statistics, physics, and applied mathematics. In finance and economics, the researcher used the time series model to model and analysis price process (e.g. [12] and [13] used autoregressive generalized autoregressive conditional heteroscedasticity (AR-GARCH) models for predicting stock market price). Recently some studies apply the ARMA-GARCH model to construct indices in the market (e.g. [14]
used ARMA(1,1)-GARCH(1,1) to form an index to measure the US citizenry’s level of socioeconomic content). In physics, [15] applied ARIMA modeling for imputation, filling in missing data in astronomical time series. They proposed continuous-time autoregressive models such as CARMA as an alternative method for managing extraordinary observations. In general, we note that Econometrics provides quantitative methods to explain quantitative problems in science and engendering.

In Electricity price forecasting, [16] and [17] used the Auto-Regressive Integrated Moving Average (ARIMA) to analyze and forecast the day-ahead spot price process from EPEX power exchange. [18] defined ARMA time series as follows:

$$\phi (L)(1 - L)^d r_t = \theta(L)a_t; \quad 0 \leq d \leq 1,$$

(2)

where $d$ is the fractional integration parameter, $L$ is the lag operator, $a_t$ refers to market shocks, $\phi$, $\theta$, $d$, and $\theta$ are the parameters of the model estimated from the data. As we observe the presence of heteroscedasticity in the return process, we believe their result is not reliable because the market experienced a high volatility period. Consequently, in this research, we apply

**Fig. 1. Price time series process from 01/02/2011 to 12/31/2018**

**Fig. 2. Return process from 01/02/2011 to 12/31/2018**
the ARMA-GARCH model to remove the linear and non-linear autocorrelation in the model. Due to the seasonality impacting electricity price processes during normal, non-spiky periods, we consider the seasonal impact on the price process in our model to extract the global trends and business cycles of a time series. Because electricity spot prices can exhibit large deviations, we consider a skew-normal distribution for model's innovations. Therefore, we apply SARIMA-GARCH with skew-normal distribution for model innovations in predicting a one-day ahead price process. The mathematics representation of our proposed model for price process is (see [18]).

\[
\begin{align*}
\phi (1 - L^d)(1 - L^s) \epsilon_t &= \theta(1 - L^k)z_t; 0 \leq d \leq 1 \\
\epsilon_t &= \epsilon_{t-1} \sim \text{iid} \\
\sigma_t^2 &= \gamma + \delta \epsilon_{t-1}^2 + \beta \sigma_{t-1}^2
\end{align*}
\]

where \(d\) is the fractional integration parameter, \(L\) is the lag operator, and \(\epsilon\) refers to market shocks, \(\epsilon_t\) are iid variables with skew-normal distribution, \(\sigma_t^2\) is the conditional variance, \(\phi\), \(s\), \(d\), \(\theta\), \(\gamma\), \(\delta\), and \(\beta\) are the parameters of the model estimated from the data. The skew-normal distribution is a continuous probability distribution that generalizes the normal distribution to allow for non-zero skewness. Probability density function (pdf) of the skew-normal distribution with parameter is \(\alpha\) given by:

\[
f(x) = \frac{2}{\omega \sqrt{2\pi}} \exp \left( -\frac{(x - \epsilon)^2}{2\omega^2} \right) \int_{-\infty}^{\epsilon} \frac{1}{\sqrt{2\pi}} e^{-\frac{t^2}{2}} dt.
\]

where \(\epsilon\) is location, \(\omega\) is scale, and \(\alpha\) is shape parameters (see [19]).

3. RESULTS

In this section, we fit time series models to return the process to predict 24 hours ahead return process. We search for the best model by comparing via AIC and BIC. The AIC and BIC measures point to an ARIMA(1,0,3) Model Seasonally Integrated with Seasonal AR(24) and MA(24), while the variance model is GARCH(1,1). Table 1 reports the estimated parameters of the SARIMA model with the T-statistics and P-values. As we observe from Table 1, all coefficients of the model are significant at a 5% confidence level.

We report the estimated values for the variance model in Table 2. Again, the ARCH and GARCH coefficients are significant at a 5% confidence level.

The data form 01/02/2011 to 31/12/2018 for electricity prices have been taken from the ERCOT. The proposed SARIMA-GARCH model with the Skew-Normal Distribution is applied to the real data from ERCOT. We use the SARIMA-GARCH model with the Normal Distribution to compare results with our model. For the sake of a fair comparison, the forecast for the 11/11/2018 is selected. Fig. 3 shows the waveform and the forecasted trend of one day ahead of electricity prices for ERCOT. The values for the next 24 hours of ERCOT is given in Table 3. The real values and compared model predicated values are two other items of the forecasting process are given in Table 2.

As can be seen from Fig. 1, the proposed method outperforms the other examined model. The square errors for the proposed model and the considered model are 0.3183 and 3.8722, respectively. The absolute errors of the proposed model (0.4785) and the checked model (1.9490) prove that the proposed method's accuracy is better than the other one. This finding confirms that the forecast accuracy can be significantly improved by the proposed method.

<table>
<thead>
<tr>
<th>Table 1. SARMA model estimated parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value</td>
</tr>
<tr>
<td>-------</td>
</tr>
<tr>
<td>Constant</td>
</tr>
<tr>
<td>AR {1}</td>
</tr>
<tr>
<td>SAR {24}</td>
</tr>
<tr>
<td>MA {3}</td>
</tr>
<tr>
<td>SMA(24)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 2. GARCH model estimated parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value</td>
</tr>
<tr>
<td>-------</td>
</tr>
<tr>
<td>Constant</td>
</tr>
<tr>
<td>GARCH{1}</td>
</tr>
<tr>
<td>ARCH{1}</td>
</tr>
</tbody>
</table>
4. CONCLUSION

In this paper, we proposed a new price forecasting method based on SARIMA-GARCH models with the Skew-Normal Distribution as electricity spot prices exhibit large deviations. Using the most recently published prices, the SARIMA-GARCH method is examined for the Electric Reliability Council of Texas price prediction in the USA market. The results were compared with RIMA-GARCH with the normal distribution. The result from the comparisons obviously exhibits that the proposed method is far more accurate than the other forecast method.

COMPETING INTERESTS

Authors have declared that no competing interests exist.
REFERENCES


